Conductivity, Temperature, and Density (CTD) Observations Analysis

Procedure Number: SOP # 3.1.1.5
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1. **Title:** Review of Conductivity, Temperature, and Density (CTD) Observations

2. **Purpose:** This document defines the methodology to evaluate CTD data measured with a CTD profiler. Analyzing water density profiles provide information to determine whether a single orifice pressure sensor is suitable for measuring water level, especially in locations where water density may be varying.

3. **Background/History:** Vertical and spatial density gradients (e.g. salt wedge) can cause unacceptable errors in water level calculations when using a single, constant density value at stations with single orifice pressure sensors. During reconnaissance of project sites that might have density variations, CO-OPS may request conductivity, temperature, and density (CTD) observations using a CTD profiler every 10 to 15 minutes for 3 hours during the multiple phases of the tide (e.g. high tide MHHW, low tide MLLW, and mean tide MSL/MWL). The CTD device uses three sensors to profile water conditions: conductivity, temperature, and pressure. Its internal microprocessor can then derive specific variables such as conductance, salinity, sound speed, and depth and combine the down and up cast data into single profiles. When data in the raw .ctd format generated by the sensor are received from the field they should be stored on the K-Drive (K:\3-OET_Review_ Files\) .

4. **Scope/Applicability:** **C**OET and field crews collecting CTD observations.

5. **Main Processes:** The CastAway-CTD software is a tool to import, review, and export density profile data. The exported data should be in either MATLAB or CSV (comma separated values) format. The formats present the data by pressure in 30 decibar steps generally starting at 15 decibars. For each pressure step the data will include depth and density along with other variables. Two methods are available to determine whether the density profiles will allow single orifice pressure sensors to measure depth within 1 cm tolerance. Section 6 below discusses the use of exported .csv formatted data to assess potential depth errors. If the error is within ± 0. 2 cm of the 1 cm tolerance or if the results are questionable then the integrated method outlined in appendix A is recommended. The integrated method uses the entire density profile to calculate potential measurement errors.

6. **Detailed Sub-Processes/Checklists:** Ensure that the profiles are for a single location by reviewing the accompanying log documentation. To import, view and export density profiles open the CastAway CTD software, click the Import files icon (step 1 in figure 1) and in the "Open" window select the .ctd file type, highlight the desired files, click Open and

then in the "Files to import" window click Import. After the files are imported click on the Show files icon (step 2) and highlight the files to display the profiles (step 3). Click on the drop down menu above the graph and select Density (step 4). To export the profile data as either CSV or MATLAB click on the Export files icon (step 5) that will bring up an export files window. Set the various drop down menus as shown in (figure 2). Then click on Export and designate the same file location for the exported data as the raw .ctd data.

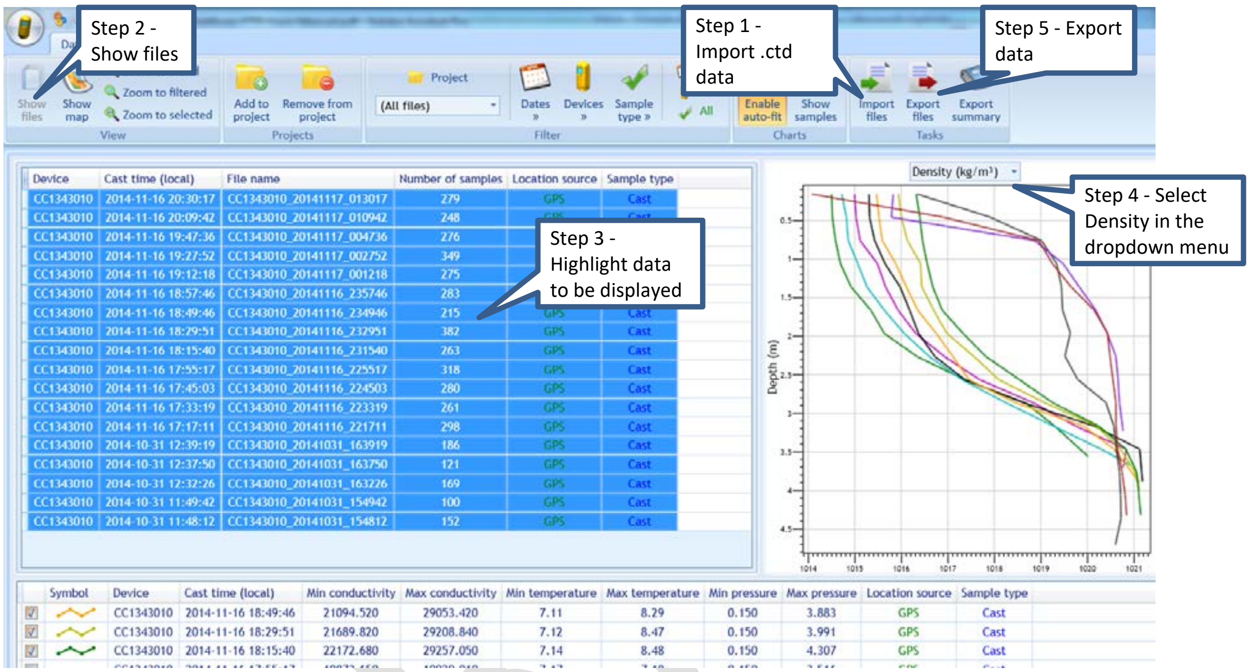

Figure 1 CastAway CTD software output

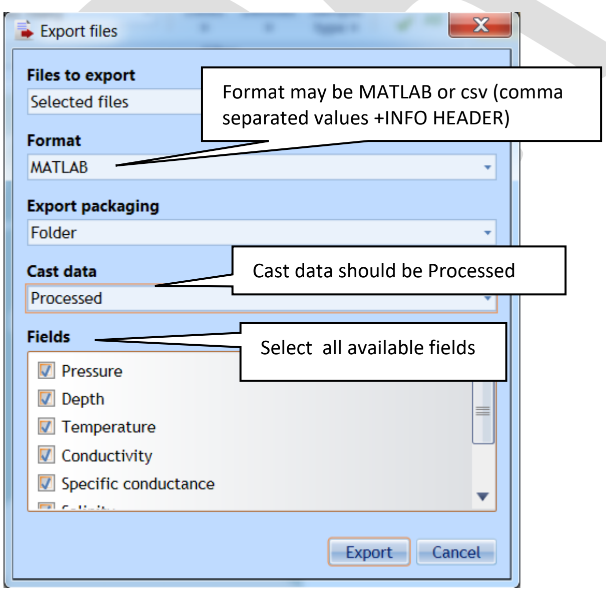

Figure 2 Export files window.

After reviewing profiles with the CastAway-CTD software open the .csv files and pick the deepest pressure common to the majority of the casts. Use the pressure value and its corresponding density to calculate depth for each cast with the following expression:

$z_{cd} = (p/\rho_c)K$ where

z_{cd} = calculated depth (m)
p = common pressure value (decibars)
ρ_c = density (Kg/m^3) at the common pressure for each cast
K = 1019.716 Kg-force/(m^2decibar)

Compare the calculated depth for each cast to the depths derived by the CTD. If the difference is greater than 1 cm then other alternative sensors such as dual orifice pressure, microwave, or acoustic should be considered for water level measurements rather than a single orifice pressure gauge. As an example, figures 3 and 4 are one of the density profiles and its .cvs formatted data from figure 1. The value 3.45 decibars is selected as the deepest common pressure because many of the other profiles include the same pressure. Using the accompanying density 1020.3131 Kg/m^3, depth is calculated as:

z_{cd} = (3.45 decibars/ 1020.3131 Kg/m^3)* 1019.716 Kg /(m^2decibar) = 3.448 m.

From figure 4 the depth derived by the CTD sensor is 3.461m, therefore the difference is $\Delta z = z_{sensor} - z_{cd}$ = 3.461 m – 3.448 m = 0.013 m = 1.3 cm which exceeds the 1 cm tolerance.

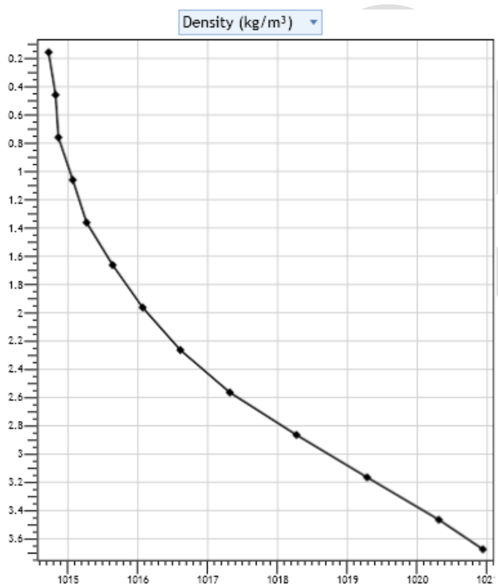

Figure 3 One of the density profiles from figure 1

Pressure (Decibar)	Depth (Meter)	Temperature (Celsius)	Conductivity (MicroSiemens per Centimeter)	Specific conductance (MicroSiemens per Centimeter)	Salinity (Practical Salinity Scale)	Sound velocity (Meters per Second)	Density (Kilograms per Cubic Meter)
0.15	0.151	7.077	20138.879	31391.819	18.842	1458.832	1014.7135
0.45	0.452	7.084	20267.120	31584.314	18.968	1459.025	1014.8135
0.75	0.753	7.089	20319.549	31661.349	19.019	1459.112	1014.8544
1.05	1.055	7.100	20582.118	32059.530	19.281	1459.487	1015.0603
1.35	1.356	7.115	20836.673	32440.977	19.534	1459.865	1015.2578
1.65	[illegible]	[illegible].131	21311.951	33164.475	20.011	1460.527	1015.6324
1.95	[illegible]	[illegible].154	21861.460	33994.512	20.562	1461.311	1016.0630
2.25	[illegible]	[illegible]	[illegible]	35033.601	21.254	1462.307	1016.603[illegible]
2.55	2.560	[illegible]	[illegible]	36397.782	22.170	1463.753	1017.315[illegible]
2.85	2.860	[illegible]	[illegible]	38222.318	23.411	1465.951	1018.2705
[illegible]	3.161	[illegible]	26202.335	40145.432	24.733	1468.404	[illegible]
3.45	3.461	7.819	27624.112	42085.520	26.074	1470.789	1020.3131
3.66017429	3.670	8.193	28737.259	43287.804	26.945	1473.314	1020.9470

Deepest common pressure value

Depth derived by CTD (z_{sensor})

Accompanying density

Figure 4 The .csv file for figure 2 and selection of a pressure value that is common to the majority of casts

7. **Quality Assurance/Control:** The steps presented in this SOP identify whether water conditions as observed by a CTD sensor are suitable for measuring water level with a single orifice pressure sensor.

8. **Management/Responsibility:** COET is responsible for updating this SOP.

Appendix

Introduction: The steps described below use the entire density profile to demonstrate potential depth measurement error. With p = pressure, ρ = unit density, g = acceleration from gravity, and z = depth, the hydrostatic equation used to calculate water depth from pressure is:

$$p = \rho g z$$

Density is a function of depth. Total pressure at depth z is given by integrating over the entire water column:

$$p_{total} = \int_0^z \rho(z) g \, \mathrm{d}z$$

ρ(z) measurements provided by the CTD result in data at discrete depth points, so a discretized version of the equation above is used to calculate total p:

$$p_{total} = \sum_{z_1}^{z_n} \rho_n g \Delta z$$

The MATLAB script 'CalcPressFromDensAndWLerror.m' found at N:\ED_Common\OET Team Folder\MATLAB_Scripts allows MATLAB to integrate pressure over the total water column and calculate the difference between true depth (the summary of the Δz's) and calculated depth, which is a function of the integrated pressure value and the bottom density value.

Method:
Review the density profiles displayed by the CastAway CTD software (figure 1) and select those with the greatest density variations for further investigation. Using MATLAB, load the script 'CalcPressFromDensAndWLerror.m'. Select a CTD profile data file of interest in .mat format and enter its load path and file name into the script (figure 1A). Enter the minimum and maximum depths measured by the CTD. The minimum depth is generally 0.15 m, but in some instances the data may have noise near the surface so select a minimum depth that is just below the noise. After all information has been entered select Run. The true depth, calculated depth, and their difference, all in meters, will be found in the Command Window (figure 2A). If the difference is greater than 1 cm, then a single orifice pressure sensor should not be considered for water level measurements. Perform the same steps for all the profiles selected.

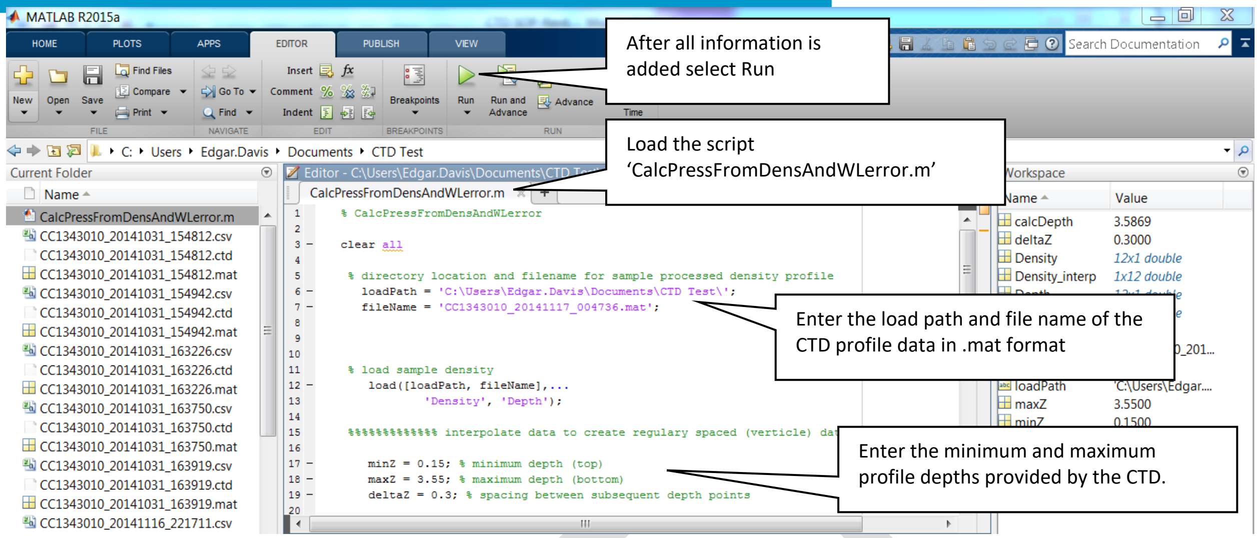

Figure 1A MATLAB Editor

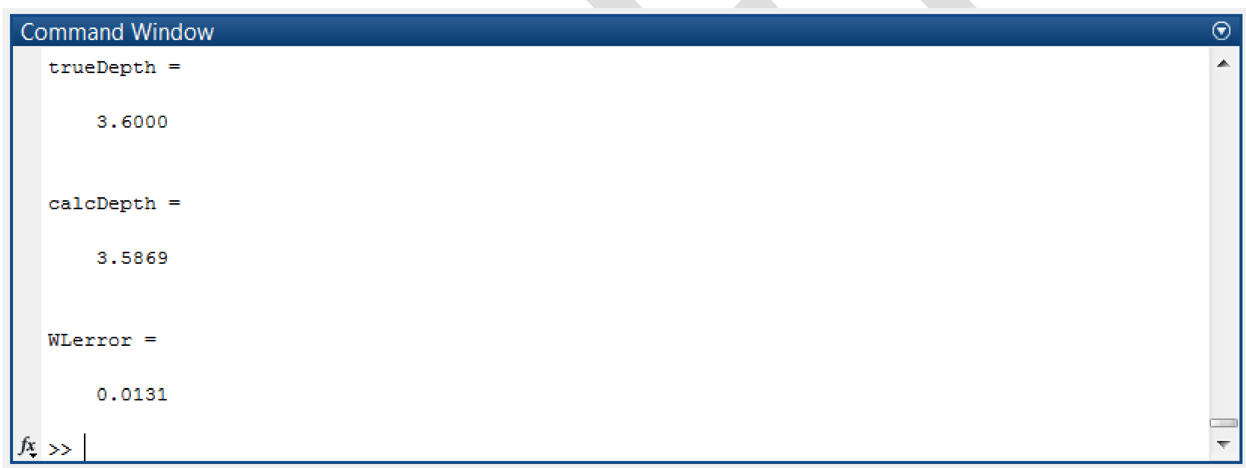

Figure 2A Command Window showing true depth, calculated depth and difference or error between the two. Results are in meters. The example shown here exceeds the 1 cm tolerance.